U. S. Army Soldier and Biological Chemical Command

# HISTORY OF CHEMICAL AND BIOLOGICAL DETECTORS, ALARMS, AND WARNING SYSTEMS

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Prepared by:

Mr. Jeffery K. Smart, Command Historian
Historical Research and Response Team
ATTN: AMSSB-CIH E5027
Aberdeen Proving Ground, MD 21010-5424

Photograph Scanning:

Mr. William H. Hauver

Editing:

Mrs. Kathleen S. Ciolfi

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For additional information on our capabilities, please contact us:

Project Manager for NBC Defense Systems
ATTN: AMSSB-PM-RNN
Aberdeen Proving Ground, MD 21010-5424

Email: pm.nbcdefense@sbccom.apgea.army.mil

## Introduction

The history of chemical agent analysis can be traced to the 17th century. The development of U.S. Army detectors, alarms, and warning systems dates back to World War I when chemical warfare was first introduced on a large scale. The next generation detectors, alarms, and warning systems will be revolutionary advancements in chemical and biological agent detection technology.

This brief history covers some of the highlights of the long history of chemical and biological agent detection technology.

Colonel Christopher J. Parker
PM NBC Defense Systems

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# PRE-WORLD WAR I

### *17th Century Vapor Detection Concepts*

One of the challenges early chemists faced was the identification of chemicals. Often the same chemical or gas would be identified differently when produced by different means. Developments in assaying in metallurgy during the 17th century led to some of the basic concepts of vapor detection and gravimetric analysis that were later used in the detection of chemical warfare agents.

- Johann Baptista van Helmont (1577-1644), born in Brussels, began to identify various gases given off by different processes like combustion, fermentation, and the heating of organic matter. While studying the chemistry of air, he shattered so many containers while generating gases from various chemical reactions, that he coined the term "gas" from the Greek word for chaos.

- In 1659, Johann Rudolph Glauber (1604-1670), a chemist who worked in Amsterdam, published information describing how the color of flame and fumes provided insight to the metal held in a flame.

- Robert Boyle (1627-1691), an English chemist and a founder of the British Royal Society, utilized flame colors, spot tests, fumes, precipitates, specific gravity, and solvent action as ways to identify chemicals.

### *17th Century Spot Testing*

Other early chemists added to the concept of chemical and gas identification by developing specific tests for detection.

- Otto Tachenius (c1620-1690), a German chemist who worked in Venice, developed a spot test consisting of nutgall extract (abnormal growth material caused by the deposited eggs of gallflies that contained tannic acid) for detecting iron compounds that helped establish the concept of qualitative chemical analysis. [1]

### *18th Century Chemical Spectrum Analysis*

Although the concept of the colored spectrum had been known since ancient times, the use of the spectrum for chemical identification did not develop until the 18th century.

- Thomas Melvill (1726-1753) observed the spectra of metallic salts in 1752.

- Adreas Marggraf (1709-1782), a German chemist, used flame colors to distinguish sodium and potassium salts in 1758.

### *19th Century Chemical Analysis Developments*

During the 19th Century, chemists continued the developments of the 17th and 18th Centuries.

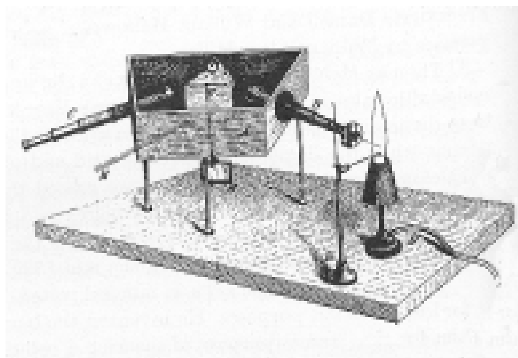
- John Herschel (1792-1871), an English astronomer and chemist, took Marggraf's concept one step further by demonstrating that when the flame colors of boric acid and the chlorides of barium, calcium, strontium, and copper were passed through a prism, they produced unique lines which could be used for identification of the item.[2]

- Justus von Liebig (1803-1873), a German chemist, developed methods for analyzing sulfur and halogens that involved the oxidation of organic materials with a nitrate in an alkaline solution.

- George Ludwig Carius (1829-1875), a German chemist, developed a method for analyzing sulfur and chlorine that involved the thermal decomposition of nitric acid.

- Robert Wilhelm Bunsen (1811-1899), a German chemist, helped contribute the Bunsen burner in 1853 that produced a colorless flame that allowed the study of spectrums. In 1857, he published a book describing gas analysis of blast-furnace fumes in England.

- In 1859, with assistance of Gustav Robert Kirchhoff (1824-1887), Bunsen developed the spectroscope which included a prism that allowed a better way to view a color spectrum. Kirchhoff also expanded on the use of spectroscopy by demonstrating that hot gases absorb the same kind of light as they emit.[3]



*An early chemical detector, the Spectroscope, developed in 1859.*

# WORLD WAR I

## *Chemical Agent Detectors*

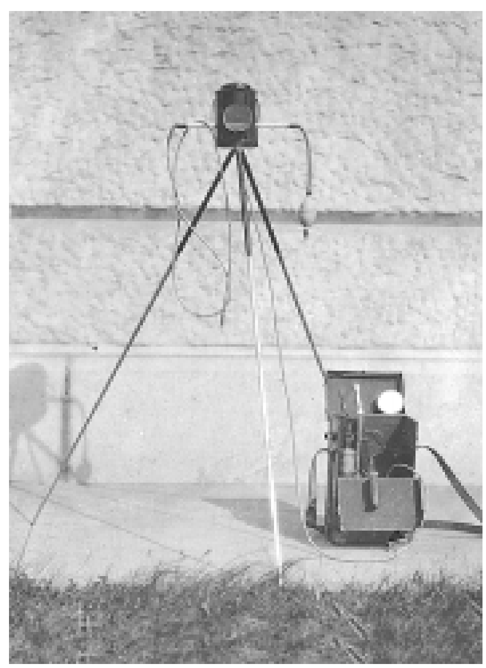
### *The Best Field Detector: The Sniff Test*

When the United States entered World War I in April 1917, although chemists in laboratories had the ability to identify chemical agents, the U.S. Army had no ability to detect chemical agents either as vapor or on surfaces in the field. Instead, the American soldier on the chemical battlefield had to rely on their own senses (smell, and throat and nose irritation) to detect chemicals. Since most of the World War I chemical agents had identifiable unique odors, the sense of smell was the best detector of the presence of chemical agents. For example, troops learned that German mustard agent smelled like mustard. Allied mustard agent smelled like garlic. Gas scouts were trained and positioned so as to provide advance warning to the main trench line of an incoming gas cloud. When the troops already had their masks on and needed to check for chemical agents, they had to perform what became known as the sniff test. This involved pulling the edge of the gas mask away from the face to allow outside air to enter the mask. If a chemical agent was present, the specific odor would alert the soldier to remain masked. Unfortunately, the sniff test was inaccurate for low levels of chemical vapor. In addition, after conducting the sniff test for several hours, a soldier would gradually lose his ability to detect low levels of mustard agent. Of course, in high levels of mustard agent, the sniff test was extremely dangerous.[4]

### *Vapor Field Detectors*

The dangers of the sniff test led to the Chemical Warfare Service's Research Division testing several concepts for a vapor field detector that did not involve removing the gas mask.

The Copper Flame Test Lantern was based upon halogen compounds burning with a green flame in the presence of copper. The process involved air passed through the suspected soil and then over copper oxide gauze heated by a Bunsen lamp burning acetylene. The mustard agent decomposed and the halogen reacted with the copper oxide gauze to produce a blue-green flame. Several versions of the lantern were developed that included a lantern, a Bunsen burner, a bulb aspirator, a tripod, and testing equipment. The test took anywhere from 2-10 minutes, but was not specific to mustard agent.



The Selenious Acid Field Detector utilized the concept that a dilute solution of selenious acid produced an orange colored suspension of selenium after contact with mustard agent. Selenious acid was prepared by mixing selenious dioxide with sulfuric acid. One of the more interesting ways to obtain the vapor was a device attached to a standard gas mask that allowed the soldier to pull the vapor into the detector by his own breath. This required inhaling repeatedly for anywhere from 30 seconds to 15 minutes depending upon the concentration of the mustard agent. This process was described as being "very sensitive to low concentration of mustard gas vapors." The problems with the detector were that it failed to detect large concentrations of some chemical warfare agents and could not differentiate between those agents it could detect.

The Iodine Pentoxide Test heated iodine pentoxide in a tube to oxidize mustard agent vapor and give off iodine. A strip of moist starch paper then detected the iodine. To avoid having to heat the tube, the Iodic Acid Test was developed for field use.

The Iodic Acid Test Field Detector used the concept that a solution of iodic acid in nitric acid released iodine that could then be detected by adding chloroform. Unfortunately, it used the same mask aspiration system that in this case required about 20 minutes of inhaling to get a good test. The test was somewhat specific to mustard agent although arsenic compounds gave a positive result also. In field tests, the procedure could detect mustard agent on the ground up to three days after the contamination.

The Hydrogen Sulfide Field Detector involved a test that absorbed mustard agent vapor, decomposed it at a high temperature, and then tested for hydrogen sulfide on lead acetate filter paper. The device was similar to the Selenious Acid Field Detector and used a gas mask to pull an air sample into a quartz tube with an absorbent. A good sample required about five minutes of heavy breathing. The absorbent was then placed in a tube with the lead acetate filter paper and heated with a gasoline blow torch for about two minutes. The test was believed to be specific to mustard agent and could detect the agent on the ground even nine days after contamination. A comparable sniff test nine days after contamination found "The odor of mustard gas was detectable . . .only when the nose was brought very close to the ground."

None of these field detectors were perfected before the end of the war.[5]

### *Detector Paints*

During the war, Chemical Warfare Service researchers at American University Experimental Station in Washington, DC, copied German work involving the use of dyestuffs that changed color when in contact with mustard agent. The Germans began painting their mustard shells with the paint and thus had an instantaneous leak detection capability, although other oils had the same effect. The Germans also put the paint on the end of a long stick that could be used to test for mustard agent in a captured trench prior to entry. A German deserter, however, reported that reliance on this test alone often resulted in casualties. American researchers developed a linseed oil paint and a du Pont lacquer/linseed oil enamel paint, both of which turned from yellow to red within four seconds of contact with mustard agent. This research, however, was incomplete by the end of the war.[6]

### *Animal Detectors*

Although dogs, pigeons, and canaries could be used to alert soldiers to the presence of toxic chemical agents, one of the more interesting investigations was that of using snails and slugs as chemical agent detectors. The objective was to find an organism that reacted differently to various gases. American researchers reported that "by combining observations on the tentacles, slime production and movements of the organism as a whole, it is possible with a little experience to tell with some degree of accuracy the kind of gas used, and in the case of chloropicrin and mustard gas distinguish certain concentrations of those gases." When a prominent French physiologist was asked to research this possibility, he burst out laughing when told it was the edible kind of snail and said French soldiers would eat the snails first. A test was conducted using French snails, but the conclusion was that the foreign snails were more conservative in their impulse to wave their tentacles. Tiger Slugs, which were a bit more sensitive and more resistant to mustard agent, were also investigated, but like the snail, became "useless" after repeated exposures to mustard agent. The final conclusion was that it "would appear unsafe to place too much reliance on their immediate behavior when placed in the presence of mustard gas in the field."[7]

### *Automatic Chemical Agent Alarm*

The French may have been the first to experiment with a combination automatic detector and alarm. A chemical agent depolarizing electrically charged needles activated the unit. This, in turn, closed a circuit leading to an alarm. The detector portion, however, lacked sensitivity to be reliable for frontline use.[8]

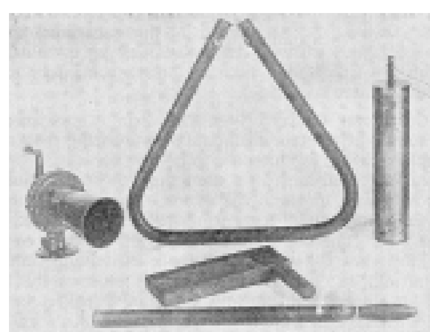
### *Failure of World War I Field Detectors*

With the establishment of mustard agent as the "King of the Battlefield" during World War I, the need for a mustard agent detector was one of the greatest unfulfilled needs of the war. Augustin Prentiss, a lieutenant colonel in the Chemical Warfare Service, summed up the state of mustard agent detectors during the war and immediately afterwards:

> *The impossibility of detecting mustard gas in the field and the insidious action of this gas, which causes no noticeable symptoms until several hours after exposure, resulted in thousands of casualties in the war which might have been prevented had there been any positive means of detecting mustard and warning troops of its presence. The great importance of this problem caused much effort to be expended in attempts to devise a reliable chemical detector which was practicable for use at the front, but these efforts proved fruitless and the problem still remains unsolved.*[9]

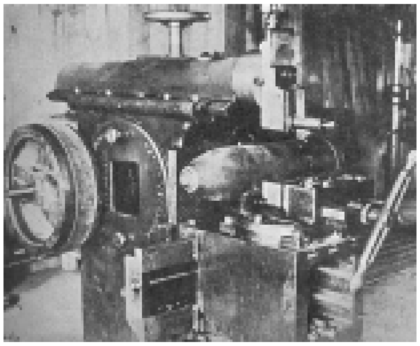
## *Warning Systems*

### *Sounding the Alert*



Once chemical agents were detected by either smell or by other means, almost anything that made a loud noise was utilized to alert the troops. This included: horns, rattles, whistles, signal horns, bells, color rockets, torches, sirens, signal lights, and even parachute whistles fired into the air. Some of these alarms, however, created problems of their own. The rattles often sounded like machine gun fire. It was also difficult to distinguish between other non-chemical alarms or loud sounds. For example, a car horn might be mistaken for a gas alarm and result in unnecessary masking.[10]

### *The First Laboratory*



On September 26, 1917, General John J. Pershing, Commander of the American Expeditionary Force (AEF) in Europe, sent the War Department a cable stating: "*Send at once Chemical Laboratory complete with equipment and personnel, including physiological and pathological sections, for extensive investigations of gases and powders. . . The laboratory. . .is for local emergency investigations to meet the constant changes in gases and powders used by the enemy and by ourselves*." The inability to conduct chemical analysis for frontline troops over 4,000 miles of telegram cable led to the establishment of a European chemical laboratory near the front in 1918. The equipment for the laboratory weighed over 110 tons and consisted of over 1,300 boxes. It took eight freight cars to move the material. This laboratory, located at Puteaux, France, near Paris, proved a great asset to the Chemical Warfare Service. Staffed with chemists, one of the key jobs of the laboratory was identifying new chemical agents used against American soldiers (photograph shows a machine used to open German chemical shells for analysis). Although it was not mobile, it provided basic chemical analytical capabilities to the American Expeditionary Force in Europe and eventually led to the concept of the field laboratory.[11]

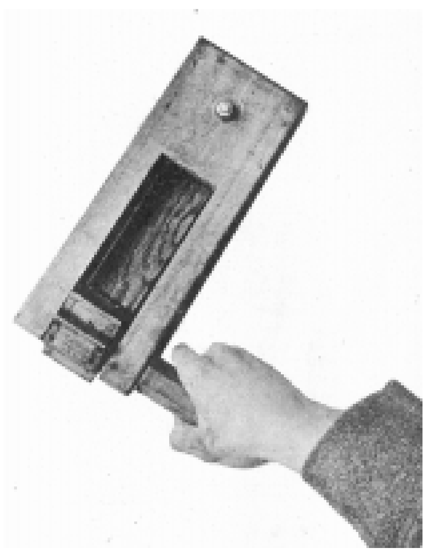
# BETWEEN THE WORLD WARS

## *Chemical Agent Detectors*

### *Military Requirement for a Chemical Agent Detector*

In December 1933, the Chief of the Chemical Warfare Service recognized that the Army desperately needed a chemical agent detector by requesting that a military requirement be established. In 1934, the Chemical Warfare Service prepared a military requirement for a chemical agent detector. This was visualized as an item that could: "detect with great rapidity the presence of one chemical agent in the atmosphere, primarily mustard gas, in the presence of other chemical agents." The fruition of this project would take several years.[12]

## *Warning Systems*



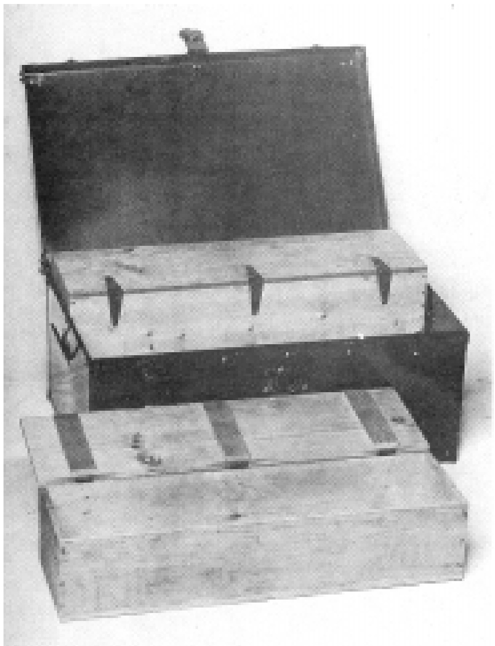
### *Standardization of Alarms*

In 1924, the Chemical Warfare Service standardized horn and rattle alarms used during the war as official gas alarms. There were three types of horn alarms: the Stewart, the Sparton, and the Klaxon. The rattle alarm was a police item.

The 1926 Training Regulation on chemical warfare provided the following information on chemical alarms:

> *There are two types of alarms to be given in case of an enemy gas attack: General alarms and local alarms. General alarms are given only in the case of cloud-gas attacks of considerable magnitude which are expected to involve a large area. Local alarms are given in all other cases. General alarms are sent out by means of all normal methods of communication such as the telephone, radio, etc. Local alarms are sent out in the same manner when necessary, but additional special-alarm devices are also provided. These special devices all depend on the production of sound as a means of giving the alarm. The most widely used of these devices is the Klaxon horn. Iron triangles, empty shell cases, and watchmen's rattles have also been used. These alarms may be installed in appropriate places or carried by gas sentries.*

The same year, the Sparton and Klaxon alarms were obsoleted. In addition, the rattle alarm was obsoleted because it sounded too much like machine gun fire.[13]



### *M1 Field Laboratory*

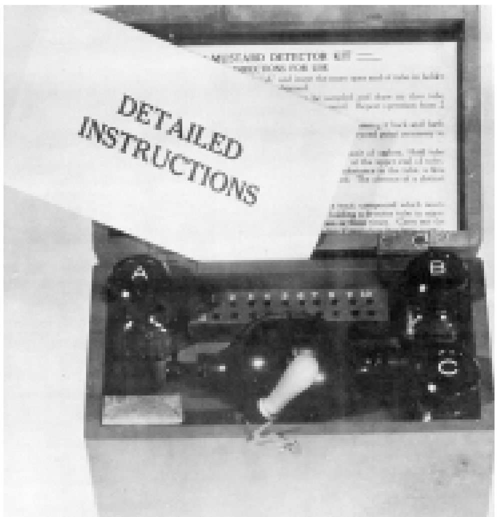
The establishment of a chemical laboratory in Europe during World War I proved the value of a frontline chemical analysis capability. Starting in 1929, the Chemical Warfare Service began work on designing a field chemical laboratory that could provide onsite analysis and identification of chemical warfare agents. The result of this project was the M1 Field Laboratory, standardized in 1936. Although it was not intended as a mobile reconnaissance system, it could be assembled and disassembled for setup at semi-permanent sites near the front. The unit consisted of 88-foot lockers, 20 boxes, and 15 crates, totaling 21,000 pounds. Seven trucks were required to move the laboratory. Eleven of the units were procured during World War II. The size of the laboratory proved too bulky for easy movement. In one test where a laboratory was sent to the Pacific Theater, there was a 60% loss of equipment due to breakage. The M1 Laboratory was eventually replaced by the M2 Base Laboratory during World War II and was obsoleted in 1946.[14]

# THE 1940'S

## *Chemical Agent Detectors*

### *M4 Mustard Agent Vapor Detector Kit*

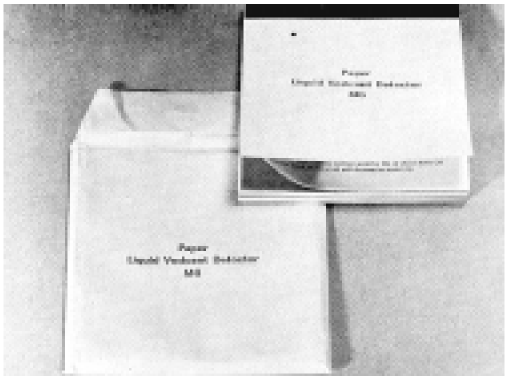
The 1934 requirements for a chemical agent detector were not met until World War II. The first standardized item was the M4 Vapor Detector Kit, which could detect even faint concentrations of mustard agent. The M4 HS Vapor Detector Kit was standardized in 1942. The key to its detection capability was a new reagent, designated DB3, discovered in 1941. DB3 reacted with mustard agent to give an intense color change. The kit consisted of 36 detector tubes, a rubber sampling bulb, developing solution, DB3 reagent, and matches, all stored in a wooden box. To detect mustard agent, contaminated air was drawn through a tube containing silica gel impregnated with the reagent DB3. The tube was then heated until a red dot temperature indicator on the tube turned yellow. After cooling, a few drops of solution were added. If mustard agent vapor was present, the solution would produce a blue color, with the intensity of the color reflective of the concentration of the agent. The kit could also detect high concentrations of chloracetophenone (CN) and cyanogen chloride (CK) agents in the air. Over 41,000 of the kits were assembled between 1942-1943. The kit was reclassified as limited standard in 1943 when the better M9 Detector Kit was standardized. It was finally obsoleted in 1945.[15]




### *M5 Liquid Detector Paint*

In early 1941, the Chemical Warfare Service investigated British detector paint similar to the dye-based ones developed during World War I. This one, however, used a blue dye designated B-1 that turned red when liquid drops of mustard agent reacted with it. Although effective as a detector, the paint was not standardized due to some of the ingredients being unavailable. Additional research established that other colors could be added to the blue dye, yet it would still turn red when exposed to liquid mustard agent. This concept eventually led to the development of M5 Liquid Vesicant Detector Paint that was standardized in 1942. The paint was olive drab and could be painted on a surface. It completely dried in about five hours and was effective up to a month. Contact with liquid mustard agent resulted in a red spot, although decontaminating agent and protective ointment could cause a false reaction. Over 7.8 million 4-ounce cans of the paint were procured during World War II. After the war, it was found that the paint also reacted similarly to nerve agents. M5 Detector Paint was obsoleted in 1956.[16]

### *M6 Liquid Detector Paper*



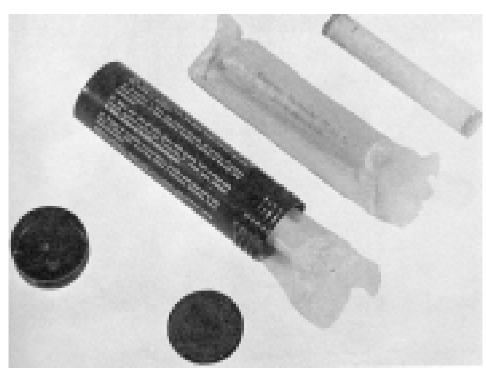
The British developed their B-1 dye based detector paint for use on paper that could be stuck on the end of a bayonet and used as a probe. The Chemical Warfare Service took the M5 Detector Paint and applied it to light Bristol board, cut it up in small pieces, and bound them in a booklet form which was standardized as M6 Liquid Agent Detector Paper in 1942. Over 1.1 million books of 25 sheets were procured during the World War II. The paper functioned similar to Detector Paint and required liquid mustard agent to fall on the paper to react. After the war, the paper was found to detect nerve agents in a similar manner. M6 Liquid Agent Detector Paper was obsoleted in 1963.[17]

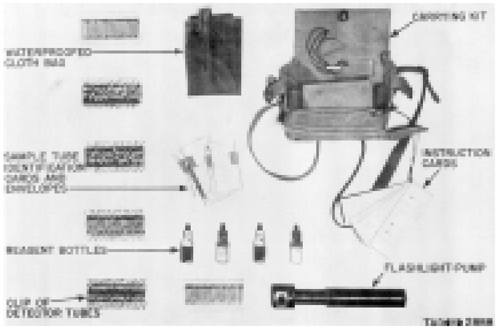
### *M7 Detector Crayon*

The need for a detection capability that could detect mustard agent already on a leaking chemical shell or other surfaces resulted in the concept of the detector crayon. B-1 dye proved inappropriate for this use, so the Chemical Warfare Service switched to Impregnite I and congo red dye. These materials were held in the shape of a crayon by a wax, initially Johnson's "Glocoat." Further improvements led to the use of different types of wax. The crayon could be rubbed on a surface or crumbled and then sprinkled over a suspected contaminated surface. Upon contact with mustard agent, the pink color of the crayon turned blue. Unfortunately, the test was not specific to mustard agent since other vesicants and some acids would also give a positive result. Nitrogen mustards, however, produced no immediate response although the crayon would latter turn yellow. During the war, 12 crayons were packed in a standard cartoon. Later, only three crayons were packed in a screw-top metal can. The M7 Vesicant Detector Crayon was standardized in 1942. Over 600,000 packs of the crayons were procured during World War II. After the war, it was discovered that the crayon also reacted with nerve agents, turning yellow instead of blue. The Army procured 300,000 packs of the crayons after the war. The M7 Crayon was obsoleted in 1965.


### *M7A1 Detector Crayon*

The M7A1 Vesicant Detector Crayon was standardized in 1949 for use with the M9A1 Chemical Agent Detector Kit. It was a shorter than the M7 version to fit in the M9A1 Kit, but otherwise was essentially the same and could detect both mustard and nerve agents. The Army procured over 300,000 packs of the crayons.[18]






### *M9 Chemical Agent Detector Kit*

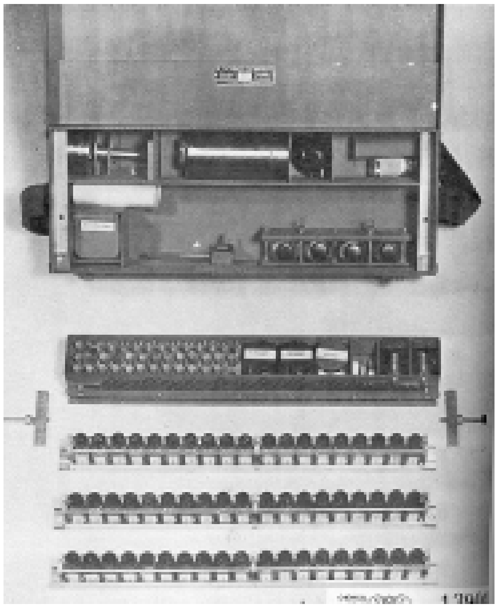
The development of the M9 (MIT E5R3) Chemical Agent Detector Kit in 1943 proved to be one of the most significant developments of the Chemical Warfare Service during the war. Described in news releases as being "effective as a modern burglar alarm," the kit consisted of a sampling pump, bottles of reagents, and detector tubes, all held in a small case that weighed about two pounds. A flashlight was added for night detection. The detection process involved pumping contaminated air into the detector tubes, which held silica gel as an absorbent. Color changes indicated the presence of specific chemical warfare agents. The kit could detect small amounts of 11 different chemical agents. It was simple to use and did not require a chemist to make the tests. Over 82,000 M9 Kits were procured during World War II. The Navy standardized a similar kit designated the Mark I Vapor Detector Kit. Although it was noted that "If active gas warfare had been initiated these kits would have provided the basic detecting medium for practically all units," it was also discovered that the M9 Kits did not detect field concentrations of Hydrogen Cyanide (AC) and any of the nerve agents. The M9 Kit was obsoleted in 1954, and the remaining stockpile converted to M9A2 Kits.

### *M9A1 Chemical Agent Detector Kit*

The M9A1 (E13) Chemical Agent Detector Kit was standardized in 1947. The primary different was the addition of detector tubes for Hydrogen Cyanide (AC) in place of the nitrogen mustard tubes since the nitrogen mustards could be detected by other tubes. Only about 500 of the kits were procured. The M9A1 Kit was obsoleted in 1952 when the M9A2 Kit replaced it.[19]

### *M10 Chemical Agent Analyser Kit*

During the war, there was a need for a kit for collecting more complete data and samples of agent in the field by chemical laboratory units than was possible with the smaller M9 Detector Kit. At the same time, there was a requirement for a small compact laboratory that could be used by technical intelligence teams and that could be carried in a standard cargo truck. These duel requirements were partially met by the standardization of the M10 (E10) Chemical Agent Analyser Kit in 1945 for use with M3 Mobile Laboratory. The kit was designed for use by a technician trained in chemistry and therefore was not issued to field troops. It could detect most chemical warfare agents except nerve agents, by using detector tubes, detector papers, and detector solutions. It came in a metal box that weighed 26 pounds. The Chemical Corps procured only 45 of the kits. The M10 Kit was obsoleted in 1952 when the M10A1 Kit replaced it.[20]

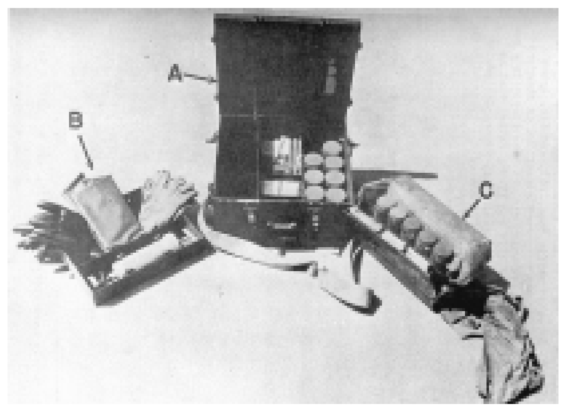


***M11 Smoke Identification Kit***

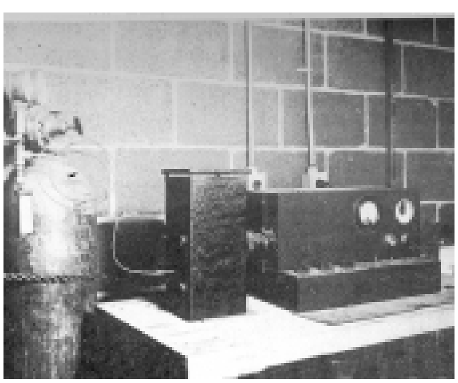
The need for a high quality smoke identification kit for use with M3 Mobile Laboratory resulted in the standardization of the M11 (E11) Smoke Identification Kit in 1945. Similar to the M10 Kit, it was designed for use by chemical technicians or other specially trained personnel. The kit could identify most toxic smokes and other non-toxic smokes. The complete kit came in a metal box and weighed 24 pounds. Only about 80 of the kits were assembled. Although the kit met its requirement, there was little concern for identifying non-lethal smokes in the field and the M11 Kit was obsoleted in 1956.[21]

***M12 Agent Sampling Kit***

The M12 (E12) Agent Sampling Kit was standardized in 1945 for use with the M3 Mobile Chemical Laboratory. Although it was designed only to collect liquid or solid agent samples of persistent agents in the field, it also contained detector paper for more immediate identification. The sampling bottles and storage containers were stored in a metal box. The Kit was designed only for use by technically trained operators. Only seven kits were procured during the war. Between 1951-1961, the Army procured 347 kits and the Air Force 37 kits. The M34 Refill Kit for the M19 CBR KIT replaced the M12 Kit. The M12 Kit was obsoleted in 1967.[22]




***Halide Photometer Automatic Chemical Alarm***



During World War II, the concept of an automatic chemical agent alarm was continuously studied, but not perfected by the end of the war. The Halide Photometer Alarm was about 30-inches long by 10-inches wide and 12-inches high. It required a hydrogen cylinder also. The detector used a Beilstein lamp attached to a photoelectric cell. When halides burned in the flame of the lamp, copper halide was formed and burned a green color. By using colored filters, a photoelectric cell was sensitized to the green color. Upon activation, the cell closed a circuit that set off an alarm. Edgewood Arsenal developed three test units and installed them in the Mustard Agent Plant at Rocky Mountain Arsenal. One unit activated immediately due to contamination already present. The only way to continue with the test was to decontaminate the portions of the plant that were contaminated. The primary problem with the concept was that the detector lacked sensitivity and selectivity between chemical agents. Due to these problems, the unit was never standardized.[23]

### *Nerve Agent Automatic Alarm Requirement*

The Germans had developed nerve agents during World War II and the United States called them "G-agents." The requirement for an automatic nerve agent alarm was formalized in 1947. The objective was to develop an automatic detection system that detected the odorless and colorless nerve agents. After detection, the system then was required to sound an alarm. Although several projects were initiated immediately, it would take another decade to actually standardize an automatic nerve agent alarm.[24]

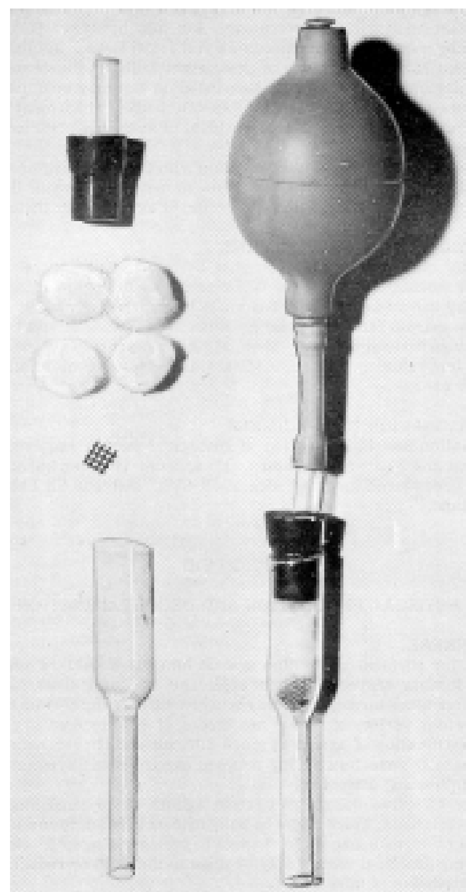
## *Biological Agent Detection*

### *Biological Agent Field Detection Capability*

The need for a biological agent detector was not apparent to the Army prior to World War II. Only when rumors of the extensive Japanese and German biological warfare programs became apparent did the United States started their own biological weapons program. The field detection of biological agents, however, was not feasible with the current technology. Unlike chemical agents, biological agents were normally not detectable by any of the five senses. This created a tremendous challenge to develop and standardize a field detection capability. This deficiency would not be met for 50 years. Until then, the Army had to rely on field sampling and laboratory identification.

### *Smears and Cultures*

The laboratory use of swabs to contaminate agar plates proved more convenient and quicker than animal inoculation in some cases. However, prior knowledge of the agent was needed to use the proper solution on the swab and the proper agar medium. Researchers also used smears on slides for microscopic examination.[25]



### *Field Sampling*

Although the Chemical Warfare Service developed several sampling procedures for biological agents during the war, the difference in the various biological agents prevented standardization of any one procedure. The Cotton Impinger was the most useful for collecting air samples. It pulled air through a cotton wool filter that collected suspended organisms.

The limits of field sampling without a detection capability were clearly demonstrated during a major biological warfare scare during the war. Starting in December 1944, the Japanese began sending unmanned balloons holding bombs over the United States. The initial concern was that they held biological agents. The Chemical Warfare Service dispatched specialized teams of biological warfare officers to sample the bombs' fillings. Without a field detection capability, these samples had to be sent to Fort Detrick, Maryland, for analysis. This created a significant delay in identification. Luckily, all the samples were negative for biological agent.[26]

### *Animal Detectors*

The use of animals to detect biological agents was one early method used in most laboratories and plants. Susceptible animals such as the guinea pig, rat, or rabbit were inoculated with samples of the suspected agent and then watched for reaction. This concept was actually used as an early field detector in Hawaii shortly after Pearl Harbor. Fear of a follow-up Japanese biological attack led the Chemical Warfare Service to put small fish in aquariums at key locations. Daily drinking water samples were put in the aquariums to test for poisons. According to a 1944 biological warfare emergency response plan, "The presence of dead fish in the aquarium calls for immediate investigation." The use of animals, however, was only suitable for certain agents and normally did not provide an immediate response. This limited their use to primarily research laboratories.[27]

## *Warning Systems*

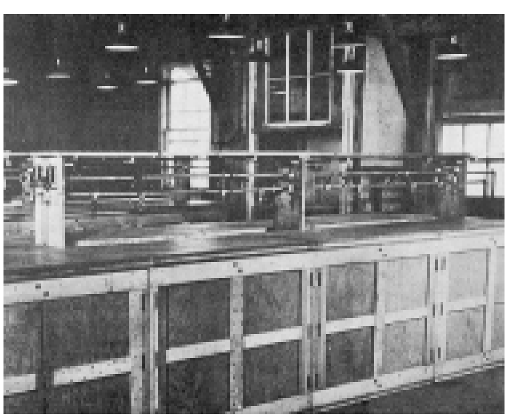
### *M1 Gas Alarm*

During World War II, the Army tested a number of percussion-type gas alarms. They included triangles, tubes of various materials, cylinders, 75mm and 105mm shells casings, and drums. Of all the items tested, the metal hollow tube in a U-shape proved the most satisfactory. The final result was the M1 Gas Alarm, standardized in 1942. It consisted of a steel tube about 1-1/2-inches in diameter and about 15-inches long. A striker, consisting of a steel tube with a wood handle, was used to hit the tube. Over 77,000 M1 Alarms were procured during the war. The alarm was obsoleted in 1951.[28]

### *M1 Civilian (Ratchet Type) Gas Alarm*

This alarm was intended for civilian air raid wardens in case of a chemical attack. The ratchet was 14-1/2-inches long by 3-inches and was made a maple wood with a white birch handle. The alarm was assigned an "M" number in the Army system, but was never standardized due to a change in policy not to standardize civilian type articles. The civilian ratchet alarm remained an experimental item in the Army and was obsoleted in 1946.[29]

## *NBC Reconnaissance*



### *M2 Base Chemical Laboratory*

During World War II, the concept of taking a chemical laboratory into the field led to the standardization of the M2 Base Chemical Laboratory in 1944. The purpose of the laboratory was to equip Chemical Laboratory Companies sent overseas to permit examination, evaluation, and identification of materiel and equipment pertinent to chemical warfare. The equipment was packed in 65 containers and weighed over 20,000 pounds. The packaging crates were designed to create laboratory benches. It was intended for semi-permanent installation. Only 12 of the M2 Laboratories were procured during the war. The M2 Laboratory was obsoleted in 1986.[30]

***M3 Mobile Chemical Laboratory***

In attempt to create a more mobile laboratory, the Chemical Warfare Service standardized the M3 (E1) Mobile Chemical Laboratory in 1944. This unit, when packed, consisted of 16 crates and weighed about 3,200 pounds. It could be carried in a standard truck, but still required unloading and setup before beginning laboratory operations. The reduced size limited its chemical analysis capability, but it was intended to operate in combat zones and refer more complicated analysis back to the nearest M2 Base Chemical Laboratory. It included inorganic and organic analysis sections, a chemical microscopy section, a general testing section for protective equipment, an engineering section that include a remote control portable shell tapping device and an intelligence section. Only four were procured during the war and three afterwards. The M2A1 Laboratory and the M19 CBR Sampling and Analyzing Kit replaced the M3 Laboratory during the 1960's. The M3 Laboratory was obsoleted in 1965.[31]

# THE 1950'S

## *Chemical Agent Detectors*

### *Continuing Requirement for Nerve Agent Alarms*

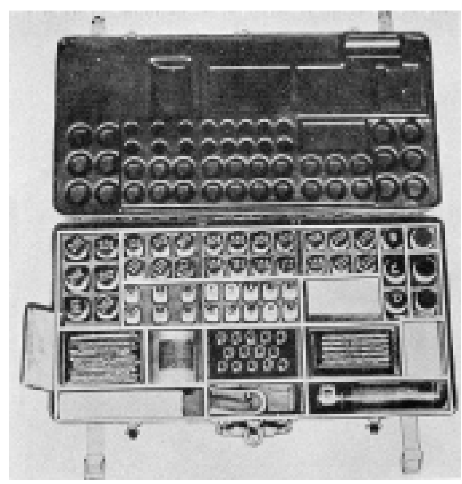
The inability to instantly detect nerve agents and to sound an alarm to alert surrounding troops was the primary concern of the Chemical Corps during the 1950s. Although field detector kits were updated to detect G-agents, these kits only provided confirmation of an attack, not advance warning. Eventually the original requirement for an automatic nerve agent alarm was split into various programs to develop different types of nerve agent alarms, to include field, remote sensing, and installation alarms for production and storage facilities.[32]

### *M9A2 Chemical Agent Detector Kit*

The M9A2 (E16) Chemical Agent Detector Kit was standardized in 1952. This version added the necessary detection capability for nerve agents (G-agents). This was the first standardized detector kit to have this capability. The kit also had a capability to collect samples of unknown chemical agents. Just over 8,000 of the M9 Kits were converted to the M9A2 version and an additional 4,000 new kits were procured. The M9A2 Kit was eventually replaced by the M18 Chemical Agent Detector Kit in 1957 and obsoleted in 1965.[33]

### *M10A1 Chemical Agent Analyzing Kit*

The inability to detect nerve agent and problems with the packaging discovered during the Korean Conflict led to the standardization of the M10A1 (E10R2) Chemical Agent Analyzing Kit in 1952. The new kit added nerve agent detection ability and a new plastic carrying case which reduced the weight to 15 pounds. The Army procured only 108 of the M10A1 Kits, the U.S. Air Force procured 165, and the U.S. Navy procured one. The standardization of the M18A2 Chemical Agent Detector Kit led to the M10A1 Kit being obsoleted in 1967.[34]



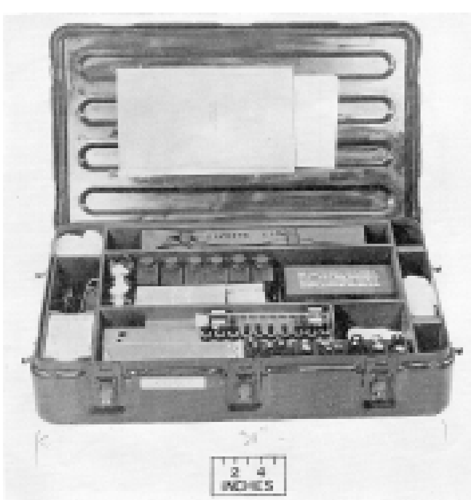

### *M2 Chemical Agents Water Testing Kit*

During World War II, the Army Medical Service developed chemical agent testing kits for water and food. After the war, the kits were improved by the Medical Service to detect nerve agents. In 1952, the Department of the Army recommended the kits be assigned to the Chemical Corps. After some debate about usefulness and the correct nomenclature, the Chemical Corps standardized the kits and changed their nomenclature.

The Chemical Corps standardized the M2 Chemical Agents Water Testing Kit in 1953. The kit consisted of reagents, a metal scoop, glassware, and cleaning equipment in a plastic case. It was designed to detect contamination of unchlorinated water by chemical warfare agents. It was not effective for use with chlorinated water. The kit was obsoleted in 1996.[35]

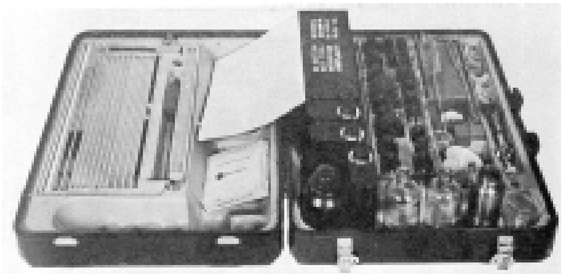
### *M3 Chemical Agents Food Testing and Screening Kit*

The M3 Chemical Agents Food Testing and Screening Kit was standardized by the Chemical Corps in 1953. The kit was used in the field to detect contamination of food or food packages by chemical warfare agents. The kit consisted of chemical reagents, a vesicant detector crayon, medicine droppers, test papers and notepaper in a plastic case. It was designed to test for arsenicals, mustard and G-series nerve agents. Over 10,000 of the kits were eventually procured and issued to medical units, survey teams, veterinary inspectors, and bakery units. Although improved over the years, the M3 Kit was obsoleted in 1967.[36]




### *M4 Poisons Water Testing Kit*

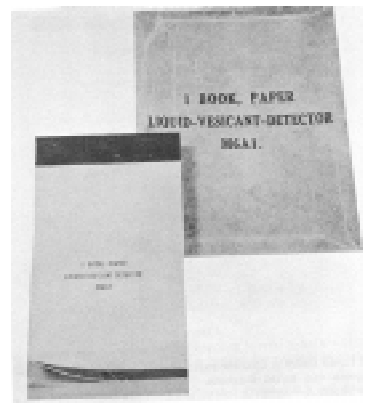
The Chemical Corps standardized the M4 Poisons Water Testing Kit in 1953. The kit consisted of a chest, flasks, cylinders, beakers, funnels, pipettes, colorimeter, ion exchange column, and reagents. It was used to make qualitative determinations of mustard agent, arsenicals, the G-agents, cyanide agents, and other heavy metal poisons in water. It was designed for Army Medical Service personnel to certify drinking water supplies. The kit was obsoleted in 1959 when the M4A1 Kit replaced it.



***M4A1 Poisons Water Testing Kit***

The M4A1 Poisons Water-Testing Kit was standardized in 1959 to improve the packaging deficiencies of the M4 Kit. It was used in conjunction with a water-testing and screening kit to measure the concentration of previously identified chemical warfare agents in water, to determine the feasibility of treating the water, to determine the quantity of chemicals needed for treatment, and to test whether the treatment had been successful. The kit consisted of chemical reagents for making quantitative analyses of water by cholorimetric determination. In 1962, a V-agent determination capability was added to the kit. The Army procured over 900 of the kits between 1951-1966. During 1962-63, the Air Force procured 137 M4A1 Kits for use in Vietnam. The kit was obsoleted in 1970 in favor of the M2 Chemical Agents Water Testing Kit's "go-no-go" detection capability.[37]

***M6A1 Liquid Vesicant Detector Paper***




The original size of the M6 Liquid Detector Paper sheets, five-inch square, proved too large. A smaller sheet size version, designated M6A1 Liquid Vesicant Detector Paper, was standardized in 1954. It could detect G-agents in addition to mustard agent. Almost 40,000 of the M6A1 books were procured during the 1960s. M6A1 Paper was obsoleted in 1996.[38]

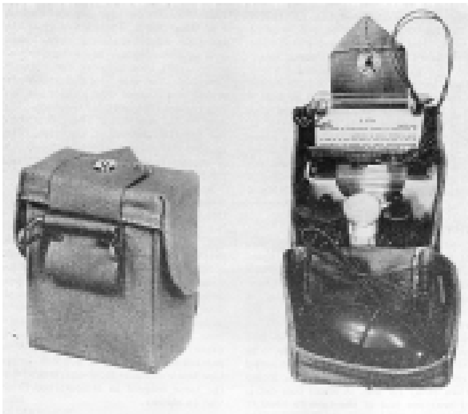
***E33 Remote Sensing Alarms***

The requirement for a remote sensing alarm was for an automatic warning device that could scan a large area and detect a chemical agent at a safe distance. In 1954, the Corps began development of a small, simple alarm commonly called LOPAIR (long-path infrared). The principle behind this device was that the G-agents absorb certain portions of the infrared spectrum. Such a device would scan the atmosphere continuously in advance of troops and give a warning alarm when G-agents were spotted.

The prototype model, designated the E33 Area Scanning G-Agent Alarm, performed satisfactorily up to about 300 yards, but weighed over 250 pounds and used too much electrical power.

An improved version, designated the E33R1, reduced the weight to 34 pounds and the power consumption to a reasonable amount. These reductions, however, resulted in the effective range of detection being reduced to 100 yards. The response time was 3-10 seconds.

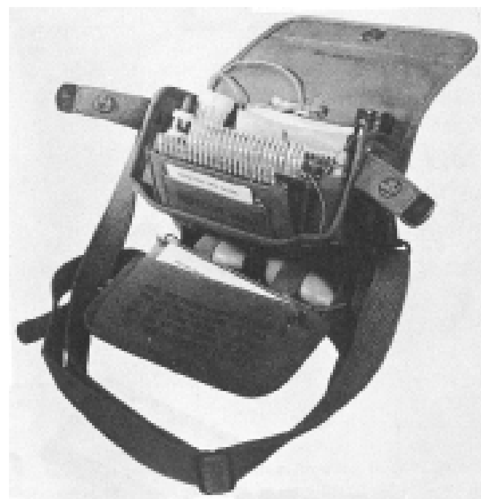
A third version, designated the E33R2, was the most successful. It combined the best of each unit with a slight weight increase but less power consumption and an increased range of 1/4 mile. The alarm consisted of an infrared source, optical reflector, optical collecting system, grating monochromator, and other electronic devices. It was designed to respond to nerve agent within seven seconds. This unit was approved for procurement for additional testing in 1955. The E33 series of alarms were never standardized.[39]



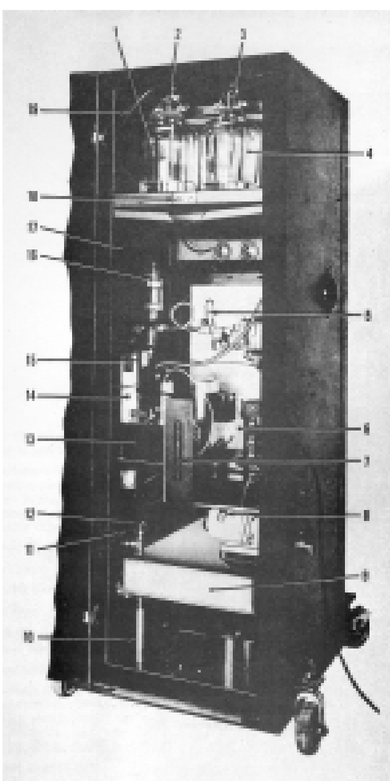
***M15 Chemical Agent Detector Kit***

The requirement for a simplified detector kit originated with the Navy based on the need for a shipboard detector to determine whether masks should be donned or doffed. To meet this requirement, the M15 (E27R4) Chemical Agent Detector Kit was standardized 1956 to detect dangerous vapor concentrations of nerve agent (G-agents) and mustard agents. These agents were detected by observing color changes in detector tubes. The kit consisted of a canvas carrier worn on the belt, an air-sampling bulb, detector tubes, and reagents.[40]

***M18 Chemical Agent Detector Kit***

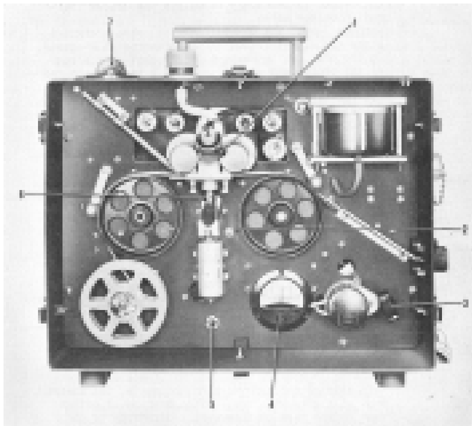


An improved version of the M9A2 Detector Kit that provided increased test sensitivity, ease of operations, all reduced weight and size was standardized as the M18 (E28) Chemical Agent Detector Kit in 1957. It consisted of a canvas carrier for over the shoulder, sampling and testing equipment, chemical reagents, and accessory equipment. It could detect most dangerous chemical agent vapor to include G-agents. The kit also had a sampling capability when the agent could not be identified by any test. It was designed primarily to detect the continuing presence of a chemical agent that was already identified so that a decision could be made about whether to unmask. Over 19,000 M18 Kits were procured until it was obsoleted in 1965.[41]



***M5 Automatic G-Agent Fixed Installation Alarm***

The requirement for an alarm for nerve agent production and storage facilities was developed in 1951. After seven years of development, the Chemical Corps standardized the M5 (E17) Automatic G-agent Fixed Installation Alarm in 1958. This was the first automatic nerve agent detector and alarm standardized by the U.S. Army. The detector portion of the alarm was based on the Schoenemann reaction utilizing a reagent solution which in the presence of G-agents, produced florescent indoxyl. A photometer measured the florescence and fed the information to a continuous-trace recorder that activated the alarm. The unit could detect G-agent and sound an alarm in about 10 seconds. Unfortunately, the unit was seven feet high and two feet square and weighed 725 pounds. Each unit cost over $10,000 and required continuous fluid replacement to remain active. Only 31 units were procured for mainly Rocky Mountain Arsenal. A converter to allow VX detection was added later. The M5 Alarm was obsoleted in 1979.[42]



### *M6 Automatic G-Agent Field Alarm*

The first automatic G-agent field alarm developed by the Chemical Corps was standardized for the Navy. This was also the first electronic device developed by the Chemical Corps for field use. The Chemical Corps standardized the M6 (E21) Automatic G-Agent Field Alarm for the Navy in 1959. The Army considered several versions of the alarm and actually procured 44 units, but rejected it for standardization due to its inability to detect V-agents and other logistical problems. The M6 Alarm was contained in a 24-pound aluminum case approximately 7-inches by 15-inches. The operation of the alarm was based on the Schoenemann reaction similar to the M5 Alarm. Color formed when any G-agent came into contact with a reagent. Design of the alarm provided that a drop of this combined solution was placed upon a paper tape which was moved (every five minutes) under two sampling spots, one of which sampled ambient air while the other acted as a monitor to minimize the effects of variations in light reflected from the paper and fluctuations in electronics. The two spots on the paper were viewed by two balanced photo cells. If color developed on the sample side, unbalance occurred between the cells and the buzzer alarm triggered. As designed, it would function continuously unattended for a 12-hour period at which time it required fresh solutions and new tape. One problem with the alarm was that it did not function below freezing. Another problem was that it ran off a battery. Despite these problems, the Navy procured over 500 of the units for its dockyards and 10 for shipboard use. The M6 Alarm was obsoleted in 1970.

### *M6A1 Automatic G-Agent Field Alarm*

Along with the M6 Alarm, the Chemical Corps standardized an improved version for the Navy designated the M6A1 (E21R2) Automatic G-Agent Field Alarm. This alarm had an improved air pump, tape take-up reel, a transformer to allow AC current, and relocation of various other elements. The Navy procured 169 of these units for dockyard use. The M6A1 Alarm was obsoleted in 1970.[43]

## *Biological Agent Detectors*

### *Biological Agent Field Detection*

The lack of biological agent field detection remained a problem throughout the 1950s. The Chemical Corps Technical Committee commented in 1957 that: "*The detection of BW agents presents a problem no less important than the detection of the corresponding CW agents which has been duly recognized with the development of appropriate equipment for sampling, detecting, analyzing, and confirming the specific agents involved in any circumstance.*" Biological agents, however, were live agents and required far more complication to create a field detection capability. Instead of detection, the Chemical Corps concentrated on sampling equipment. Field manuals during the 1950s for biological warfare stated that the first indication of a biological attack would be widespread illness. Medical treatment would have to begin before identification of the specific biological agent, which might take days or even weeks. Much like the World War II procedures, the manuals advised that field samples would have to be tested and identified at Army Medical laboratories. Early sampling kits were described as field expedient collections of the pertinent items such as test tubes, air sampler, and notebooks.[44]

### *M17 Biological Agent Sampling Kit*

In 1951, the Chemical Corps issued a formal requirement for a biological agent sampling kit to collect samples of contaminated air, soil, and other materials for dispatch to an appropriate medical laboratory for positive identification. The M17 (E25R1) Biological Agent Sampling Kit was standardized in 1957 to meet the requirement. Due to problems with finding the right nutrient media for the various biological agents, only 50 kits were procured by the Army for training purposes. The kit was declared unsuitable for field use due to its inability to sample for all biological agents. As standardized, the kit consisted of a hand-operated vacuum pump, filtration units, sump tank, sterile plastic petri dishes, personal incubation vest, vials of nutrient broth, vials of swab liquid, cotton-tipped wood swabs, gloves, forceps, and plastic bags. The total weight of the items plus the plastic carrying case was 18-pounds. The kit was designed to collect samples from aerosols, surfaces, water, food, and materiel and to allow for initial culturing of the samples while enroute to a Medical laboratory for definitive identification. In addition to the Army, the Navy procured over 400 kits and Civil Defense procured 25 kits. The kit was eventually replaced by the M19 CBR Agent Sampling Kit and obsoleted in 1968.[45]

## *NBC Reconnaissance*

### *E4 Mobile Chemical Laboratory*

During the Korean Conflict, there was a renewed interest in the concept of the front line field laboratory that could analyze and identify chemical, biological, and radiological materials. Originally intended as a replacement for the M3 Mobile Chemical Laboratory, the E4 Mobile Chemical Laboratory was a self-sufficient unit in an aluminum trailer approximately 27-feet by 8-feet in size. It was intended to identify chemical and radiological materials, and later biological agents when the specific equipment became available. The development project was dropped in 1965 when the M3 Mobile Laboratory was obsoleted.[46]

# THE 1960'S

## *Chemical Agent Detectors*

### *M15A1 Chemical Agent Detector Kit*

An improved version of the kit, designated the M15A1 Chemical Agent Detector Kit, was standardized in 1961 to meet the Navy requirement and additional Army and Marine Corps needs. This kit could detect both G- and V-agents, in addition to mustard agent, cyanogen chloride (CK) and phosgene oxime (CX). The Army procured over 40,000 kits during 1962-64 and the Navy over 3,000 from 1962-65. The M15A1 Kit was obsoleted in 1970.

### *M15A2 Chemical Agent Detector Kit*

The addition of M8 Detector Paper in the kits resulted in the M15A2 Chemical Agent Detector Kit being standardized in 1964. The Army procured over 62,000 kits from 1965-69 and the Navy almost 5,000 from 1965-67.[47]

### *M18A1 Chemical Agent Detector Kit*

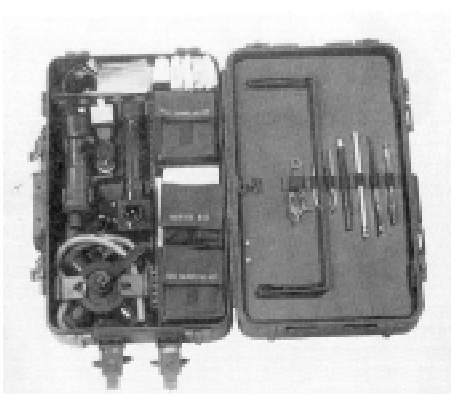
The M18A1 Chemical Agent Detector Kit, an improvement to the earlier kit, was standardized in 1961. The kit detected most known chemical warfare agents to include V-agents. The kit also included M6A1 Detector Paper and M7A1 Detector Crayons. Over 10,000 kits were procured from 1962-64. The kit was obsoleted in 1970.

### *M18A2 Chemical Agent Detector Kit*

The M18A2 Chemical Agent Detector Kit was standardized in 1964 with the addition of M8 Detector Paper to replace the earlier M6A1 Paper. Over 16,000 kits were procured from 1965-68.[48]

### *M8 Chemical Agent Detector Paper*

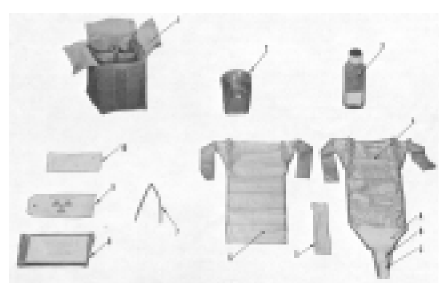
M8 (E57) Chemical Agent Detector Paper was standardized in 1963. The paper was a Canadian development and came in 25 4-inch by 2-1/2-inch sheets inside a booklet perforated for easy removal. The paper reacted with liquid chemical agents by turning dark blue for V-agents, yellow for G-agents, or red for mustard agent. A color chart on the inside cover of the booklet provided samples of the responses. One problem with the paper was that some less dangerous liquids gave positive responses. In addition to the United States, most NATO countries procured M8 Paper.[49]

### *M19 CBR Agent Sampling and Analyzing Kit*

The M19 (E34) Kit was standardized in 1964 to replace the M10A1 Chemical Agent Analyzing Kit. Usage of the kit was restricted to chemical laboratory technicians and chemical intelligence teams. The purpose of the kit was to identify enemy chemical warfare agents, perform preliminary processing of unknown chemical, biological, and radiological agents and delineate contaminated areas. The main items in the kit were color coded with fluorescent paint that allowed identification at night with a small lightweight battery-operated ultraviolet lamp. The M19 Kit was obsoleted in 1996.[50]

### *M34 CB Agent Sampling Kit*



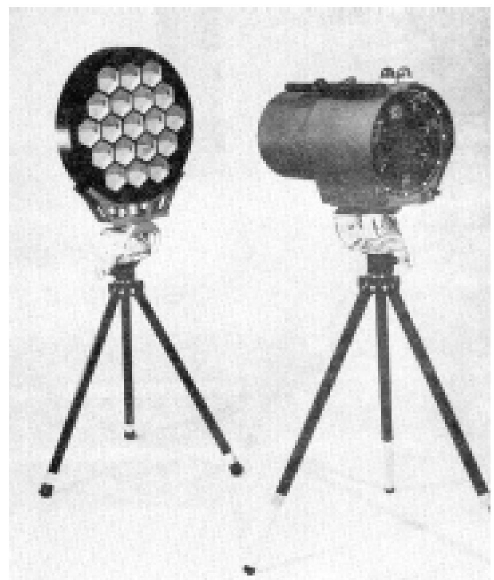
The M34 Kit was originally a refill kit for the M19 CBR Agent Sampling and Analyzing Kit and was standardized in 1964. Later it was redesignated a separate item. The kit consisted of two soil sampling kits, one container for vials, and two pairs of gloves packed in a fiberboard box. The kit was used by training personnel to sample soil, surfaces, and water for chemical and biological agents. It could also perform preliminary processing of soil samples. The M34 was replaced by the M34A1 CBR Agent Sampling Kit in 1999.[51]

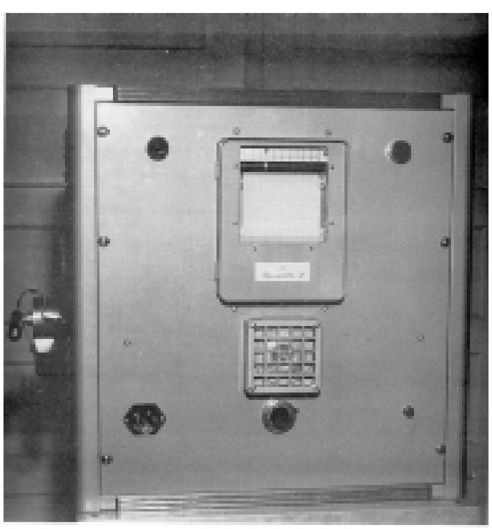
### *M7 Automatic Field V-G Agent Alarm*

The Army's dissatisfaction with the M6 Automatic Field Alarm led to the development of a field alarm that was smaller and detected both G-agent and V-agent. The M7 (E41R3) Automatic Field V-G Agent Alarm was standardized limited procurement in 1961 and standard in 1965. The alarm was described as the size of a portable typewriter and came in an insulated fiberglass case weighing 17 pounds. It was battery powered and included a vehicle fender-mounting bracket. The detector used the M6 Alarm system of treated wet tape that discolored when nerve agent was present. An integral heating unit kept the interior of the unit from freezing. Servicing of the alarm was required every 12 hours. The Army procured over 400 M7 Alarms under the limited procurement action, while the Navy procured over 40. Although additional versions of the alarm were developed, further work was halted in 1964 in favor of the M8 Alarm. The M7 Alarm was obsoleted in 1968.[52]

### *E49 Remote Sensing Alarm*

Army interest in the E49 Active Long-Path Infrared (LOPAIR) Field Alarm took priority in the early 1960s. The alarm was an area-scanning detector to give advance warning of nerve agents. It consisted of an emitter/detector infrared unit, a separate cube corner reflector, and a remote alarm headset. Infrared radiation was transmitted through the atmosphere to the reflector unit about 400 yards away and then back to the detector. The presence of nerve agents would be detected in less than three seconds. The total system weighed 77 pounds. Testing of the developmental item resulted in too much interference from airborne dust particles. The E49 Alarm was never standardized and the program terminated in 1966. Instead, the Army switched to the concept of passive infrared detection by the end of the decade.[53]





### *E59 Plant Alarm*

During the 1960s, the Army worked on a better installation nerve agent alarm for production and storage facilities. The E59 Plant Alarm attempted to meet that need and replace the earlier M5 Installation Alarm. The alarm was designed to detect G-agents and with the E60 converter, could also detect V-agents. It was more sensitive than the M8 Alarm and less expensive to operate than the M5 Alarm, although each alarm cost about $12,000. Also much smaller than the M5 Alarm, it was only 23-inches by 22-inches by 15-inches, and weighed 115 pounds. The detection process was the Schoenemann reaction that detected fluorescence by a photomultiplier tube. Less than 50 E59 Alarms were assembled by Edgewood Arsenal and used at various sites where nerve agent was present to include demilitarization sites. Although somewhat successful in their use, the E59 Alarm was never standardized.[54]

### *M8 Automatic Chemical Agent Alarm*

For the U.S. Army, the 1967 Arab-Israeli War demonstrated the important need for an automatic field alarm system for the detection of nerve agent vapor. In 1968, the Army standardized the M8 (E61) Portable Automatic Chemical Agent Alarm. The four-year development program was one of the most significant accomplishments in chemical defense and corrected a major deficiency that had left U.S. soldiers vulnerable to a surprise nerve agent attack. The M8 Alarm included the M43 detector unit and the M42 alarm unit. Additional alarms could be connected. The two units together weighed about ten pounds. The detector used an electrochemical point sampling system that continuously monitored the atmosphere and sounded an audible or visible warning of even very low concentrations of nerve agents. Actual detection occurred when air was passed through an oxime solution surrounding a silver analytical electrode and a platinum reference electrode. Presence of an agent caused a reaction in the solution, which increased the potential between the electrodes. The change in potential, when amplified, triggered the alarm signal. The unit could detect almost all known chemical agents. In 1971, the M8 alarm was reconfigured into ten different configurations for various vehicles and for field and installation use. The versions were numbered M8 (manpack), M10 (fixed emplacement), M11 (truck), M12 (truck), M13 (truck), M14 (armored vehicles), M15 (armored vehicles), M16 (truck), M17 (truck) and M18 (truck). This different numbering system was halted in 1981 and all the alarms were redesignated simply the M8 Alarm. The M8 Alarm was obsoleted in 1996.[55]

## *Biological Agent Detectors*

### *Early Concepts of Biological Agent Field Alarms*

Early work on automatic biological agent field alarms during the 1960s resulted in the development of several concepts:

- The Ratio Alarm observed fluctuation of particle size distribution in the atmosphere. A high false alarm rate was its primary problem.
- The Partichrome Alarm detected airborne bacteria through visual staining of collected samples on an oil-coated optical tape.
- The Protein Pyrolysis Alarm detected airborne protein through reduction to ammonia by pyrolysis. An ion chamber measured the decrease in current when finely divided ammonium chloride passed through it.

None of the experimental items completed development during the decade.[56]

## *NBC Reconnaissance*

### *M2A1 Base Chemical Laboratory*

During the 1960s, the M2 Base Chemical Laboratory was upgraded to include the detection of nerve agents and radioactive materials, and the collection of biological warfare samples. The result was the M2A1 Base Chemical Laboratory, standardized in 1963. The M2A1 was obsoleted in 1986.[57]

# THE 1970'S

## *Chemical Agent Detectors*

### *M256 Chemical Agent Detector Kit*

During the 1970s, the Army continued to improve the basic detector kit and standardized the M256 Chemical Agent Detector Kit in 1977. The M256 Kit could detect chemical agents in the air and liquid chemical agent contamination on surfaces. The primary use was to notify troops as to when they could unmask after a chemical attack. The kit included a plastic carrying case, 12 sampler-detectors, and M8 Detector Paper. Each kit weighed just over a pound. To detect chemical agents in the air, a plastic sampler/detector was removed from its package and the various ampoules crushed between the fingers. The reagents then flowed through preformed channels to the appropriate test spot on the sampler/detector. The resulting reaction provided a distinctive color that varied by agent. The test took about 15 minutes to complete. The M8 Paper was used to detect liquid contamination on surfaces. The M256 Kit was obsoleted when the M256A1 Kit replaced it in 1986.[58]

## *Biological Agent Detectors*

### *Biological Detection and Warning System*


The Biological Detection and Warning System (BDWS) started development in 1974 to meet the growing critical need for a field biological agent detection system. The BDWS consisted of the XM19 Chemiluminescence Biological Agent Automatic Alarm, the XM2 Biological Agent Sampler, and a M42 Alarm. The XM19 Alarm detected airborne biological material and gave an alarm when it satisfied predetermined criteria. Actual detection involved a moving adhesive tape, a wash station, and a reagent reaction station where the light-emitting reaction was converted into an electrical signal. The XM2 Biological Agent Sampler collected and concentrated biological agent aerosols manually or automatically when the XM19 Alarm activated. The sampler then kept the samples viable until they could be examined in a medical laboratory. The XM19 Detector weighed about 145 pounds and the XM2 Sampler about 140 pounds. The BDWS continued in development until 1983 when the program was canceled after the XM19 Alarm failed technical and user testing.

The BDWS would have been forgotten if it was not for Operation Desert Shield/Storm in 1990-1991. In response to an emergency requirement for a biological detector, the XM2 Sampler was retrieved from "off the shelf," refurbished, tested, and prepared for deployment to Saudia Arabia by January 1991. To complement the XM2 Sampler, the Army added disposable Sensitive Membrane Antigen Rapid Test (SMART) Biological Agent Detector Tickets, developed for laboratory use for clinical tests. The SMART Tickets used the wet collection fluid to give a positive/negative indication of the presence of a specific biological agent within 10-20 minutes. Positive results were indicated by a red or pink dot. Over 80,000 SMART Tickets were rushed into production at the rate of 30,000 per month to support the XM2 Sampler.

By the middle of March 1991, 11 XM2 Samplers were deployed to the frontlines with over 20,000 SMART Tickets. This combination was described as "*an extremely successful and reliable*" detection system. Although the XM2 Sampler filled a critical deficiency during Desert Storm, the unit was never standardized.[59]

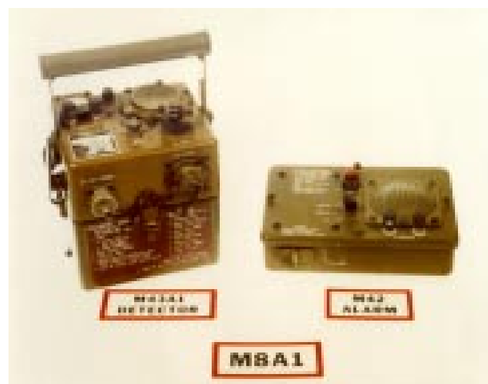
# THE 1980'S

## *Chemical Agent Detectors*

### *M9 Chemical Agent Detector Paper*

The concept of a liquid agent detector paper that could be attached to a soldier's uniform was investigated for several years. The result was M9 Detector Paper. The paper consisted of B-1 detector dye that changed color when contaminated with liquid agent. It came in a roll two-inches wide by 30 feet contained in a tear off type dispenser. Prior to adoption, testing revealed that the B-1 dye was mutagenic and possibly carcinogenic. The Army still chose to adopt M9 Detector Paper in 1980 and then found a replacement detector dye that was not mutagenic.[60]

### *M8A1 Automatic Chemical Agent Alarm*




The M8A1 Alarm was standardized in 1981 with the new M43A1 Ionization Detector. Existing M8 Alarms were upgraded by replacement of the old detector. The M43A1 Detector eliminated the electrolyte solution passing through an electrochemical cell and instead used an alpha radiation source for detection. A pump drew air samples into the detector unit and then through a heater and filter. Contaminated air passed over an alpha radiation source that caused the chemical agent ions to cluster. A geometrically configured cell collected the clusters as electric current while a monitor sensed any voltage change. Any voltage change activated the alarm. The M8A1 Alarm became the Army's single most important chemical detection capability and by 1987, over 32,000 units were in the field. During Operation Desert Shield/Storm in 1990-1991, the U.S. Army utilized over 12,000 M8A1 Alarms as the main detection capability for chemical defense.[61]

### *M272 Chemical Agents Water Testing Kit*

The need for a replacement of the M2 Water Testing and Screening Kit led to the development of the M272 Chemical Agents Water Testing Kit. The kit was adopted in 1983 for field use. It was lightweight, compact, expendable, and easy to use. The kit could detect most chemical agents in raw and treated water. It also contained simulants for training. It was intended for Quartermaster and Medical personnel to verify that water was free from chemical contamination.[62]

### *M256A1 Chemical Agent Detector Kit*

One complaint with the M256 Chemical Agent Detector Kit was that a more sensitive nerve agent test was needed in the sampler/detectors. To improve the sensitivity, eel enzyme was substituted for the original horse enzyme. The improved kit was designated the M256A1 Chemical Agent Detector Kit and was adopted for field use in 1986. The M256A1 Kit was used extensively during Operation Desert Shield/Storm.[63]

### *Chemical Agent Monitor (CAM)*

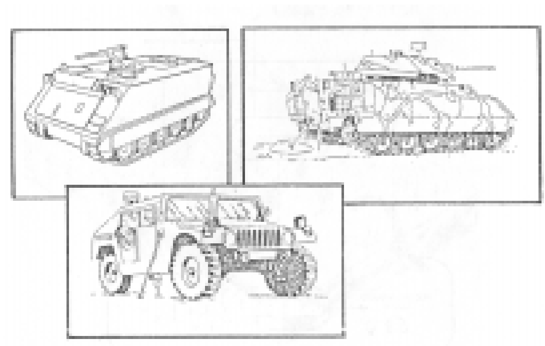
The urgent need for a lightweight hand-held chemical detector and the movement to microprocessors was reflected in the development of the Chemical Agent Monitor (CAM), type classified limited procurement in 1985 and standardized in 1988. It was a hand held device for monitoring chemical agent contamination on personnel and equipment. The small unit weighed about five pounds. The CAM detected vapors by sensing molecular ions of specific mobilities and used timing and microprocessor techniques to reject interferences. The CAM was based on a United Kingdom (U.K.) design originally standardized by the U.K. back in 1984. Fielding of the CAM began in 1988.[64]

## *Warning Systems*

### *XM207 Chemical Attack Warning Transmission System (CAWTS)*

Although automatic chemical agent detectors included an alarm, there were still problems alerting troops spread out over an area. The XM207 CAWTS was an unsuccessful attempt to provide an alarm that would alert a platoon size unit to the presence of chemical agents. The CAWTS was a small pyrotechnic whistle and three pyrotechnic flares contained in a standard ground signal rocket. It was fired by hitting a cap containing a firing pin against a percussion primer. Once the rocket was ignited, it would shoot up to about 150 meters and release the whistle and the three flares (2 white, 1 red). The XM207 failed to meet expectations, however, and development work was stopped in 1983.[65]

## *NBC Reconnaissance*



***XM87 NBC Reconnaissance System (NBCRS)***

The XM87 NBCRS was intended as a fully integrated NBC detection, warning, and communication system mounted in either an M113 Armored Personnel Carrier, an M3 Bradley Fighting Vehicle, or the High Mobility Multipurpose Wheeled Vehicle. The XM87 could detect, identify, and mark areas of NBC contamination and collect samples of contaminated materials. It could also transmit NBC contamination information and mark safe passage for other units. The Army prepared prototypes of the XM87 in the M113 carrier for testing, but in 1988, the Army decided to buy the German FUCHS armored vehicle instead of using the M113. The XM87 program was then terminated.[66]

# THE 1990'S

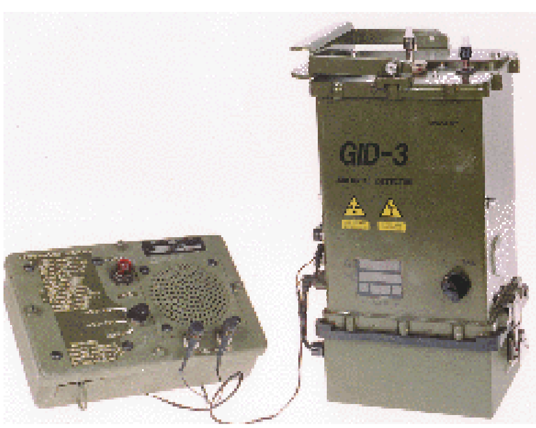
## *Chemical Agent Detectors*

### *M21 Remote Sensing Chemical Agent Alarm (RSCAAL)*

The concept of a remote sensing chemical agent alarm started in the 1950s, but research on the project continued throughout the 1970s and 1980s. Finally in 1992, the Army type classified the XM21 Remote Sensing Chemical Agent Alarm for low rate production. After additional work, the M21 Remote Sensing Chemical Agent Alarm was standardized in 1995. The M21 was an automatic scanning, passive infrared sensor which detected nerve and blister agent vapor clouds based on changes in the background's infrared spectra caused by the presence of agent vapor. The detector could "see" agent clouds out to five kilometers. The M21 was mounted on a tripod or on the M93A1 NBC Reconnaissance Vehicle, although in the latter configuration, the vehicle had to stop for the unit to function correctly. Initial production was scheduled for 156 units. Fielding of the M21 Alarm began in 1995. First deployment to the frontlines occurred when six M21 Alarms were deployed to Kuwait in 1996.[67]

### *Improved Chemical Agent Monitor (ICAM)*

Starting in 1989, the Army began a program to improve the Chemical Agent Monitor (CAM) by replacing the electronics board. The Improved Chemical Agent Monitor (ICAM) was standardized in 1993 and improved reliability, reduced maintenance costs, and eliminated the need for depot repair.[68]

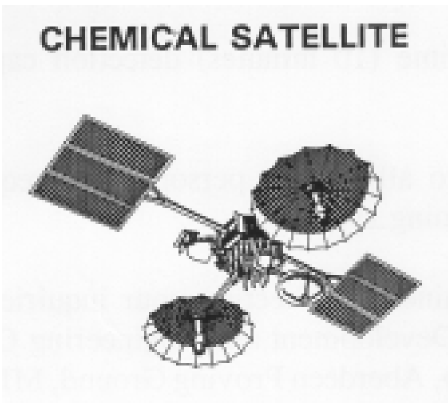



### *M22 Automatic Chemical Agent Alarm (ACADA)*

The M22 ACADA program started in the 1970s as a replacement for the M8 Alarm. After continuous development, the final version was type classified standard in 1997. The M22 was an "off-the-shelf" design that was man-portable, operated independently after system start-up, and provided an audible and visual alarm. It was an advanced point-sampling, chemical agent alarm system that augmented the CAM as a survey instrument. The unit simultaneously detected both nerve and blister agent vapor and was suitable for monitoring collective protective shelters. It was significantly more sensitive than the M8A1 Alarm and less responsive to interferences. The M22 system also provided communications interface for automatic battlefield warning and reporting. The M22 system consisted of the M88 Detector, the M42 Remote Alarm Unit, and a power supply. It can be mounted on most military vehicles. The M22 is currently being fielded to units around the world. In addition, the U.S. State Department purchased several M22 alarms for their chemical-biological response personnel.[69]

### *M34A1 CBR Agent Sampling Kit*

The need to make improvements to the M34 Sampling Kit became apparent during the 1980s. Of particular concern were the presence of glass vials as a component of the kit and outdated soil sampling techniques. The result was the M34A1 Kit adopted by the Army in 1999. The changes included eliminating items that gave the kit a shelf-life, removing breakable items, adding additional sampling components for soil, liquid, and surface samples, and adding M8 Detector Paper.[70]




### *Chemical Agent Detection Satellite*

Work on an on-the-move standoff chemical agent detection system for both ground and aerial platforms in 1990 led to the concept of a satellite-based detection system. A study group concluded that the concept was feasible for both low orbit (300 kilometers) and geosynchronous platforms. The concept was to provide a near real-time (10 minutes) detection capability with a capability to alert all combat personnel using existing warning systems. The concept was pursued, but did not reach completion.[71]

## ***Biological Agent Detectors***

### *M31 Automatic Biological Agent Integrated Detection System Alarm (BIDS)*

After the Gulf War, General Colin Powell testified to Congress that the U.S. was vulnerable to biological warfare. One reason was that the U.S. had been unable to standardize a good biological agent detector. In 1995, the XM31 Automatic Biological Agent Alarm (BIDS) was type classified limited procurement as the first biological alarm. The M31 was standardized in 1996. The BIDS was a small truck packed with sampling and detection equipment. Each vehicle could provide 24-hour monitoring with identification of the agent following an alarm in about 30 minutes. The BIDS was fielded to the first military unit whose sole mission was to detect the use of biological weapons. The first BIDS unit was the Army Reserve's 310th Chemical Company, created at Fort McClellan, AL in October 1996. Other units are currently receiving the BIDS.[72]

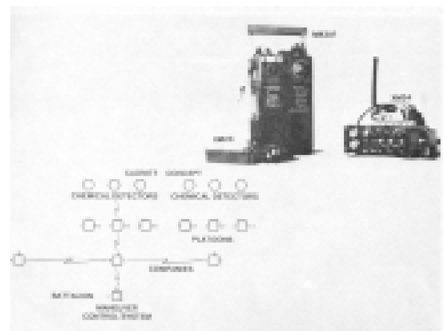
***M94 Long Range Biological Standoff Detection System (LR-BSDS)***

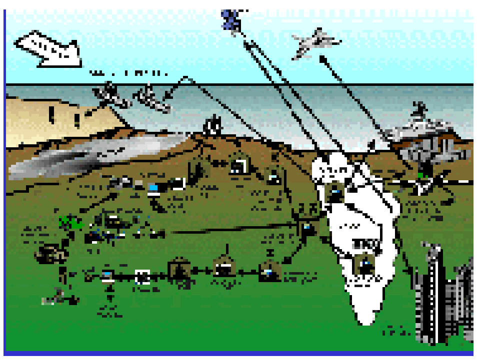
For long range detection, the Army standardized the M94 LR-BSDS in 1996. The system was intended for use on airplanes and helicopters and provided early warning, tracking, and mapping of aerosol agents. The system had the potential to detection aerosol clouds out to ranges of 100 kilometers. Early testing in 1994 demonstrated that the LR-BSDS, mounted on at UH-60 Blackhawk helicopter, could detect a biological simulant at 15-20 kilometers.[73]

### *Warning Systems*

***Chemical Agent Detector Network (CADNET)***

The CADNET was a radio frequency based system designed to provide automated alert of chemical and biological detector alarms to adjacent units and higher headquarters. The system consisted of two primary components, the XM23 Detector/Transmitter Interface and the XM24 Receiver/Radio Interface. Problems with communications compatibility eventually led to the termination of the program in 1992.[74]





***The Joint Warning and Reporting Network (JWARN)***

The JWARN is a combination of systems linking NBC detectors to tactical communications and provides NBC warning, reporting, and battlefield management. The purpose of JWARN is to standardize NBC warning and reporting throughout the Joint Services. The current configuration includes the XM33 Detector Interface Device (Transceiver) JWARN Alarm Monitor Group. The JWARN is currently being fielded to units in the United States.[75]

***Multipurpose Integrated Chemical Agent Alarm (MICAD)***

The MICAD is an integrated NBC detection, warning, and reporting system designed for area warning, combat and armored vehicles as well as tactical van and shelter systems. The purpose of the MICAD is to automate the NBC warning and reporting process throughout the battlefield. Current configurations include: the M27 NBCRS Fox Alarm Monitor Group (MICAD) and the XM32 Tactical Vehicles/Area Warning Alarm Monitor Group.[76]

### *NBC Reconnaissance Systems*

***M93 NBC Reconnaissance System (FOX)***

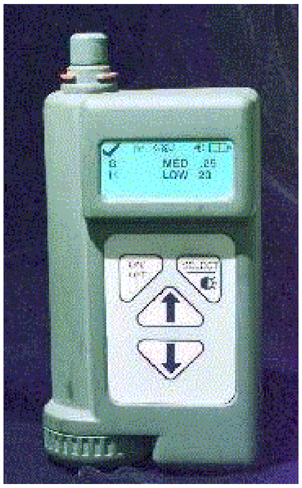
The initial work with the XM87 NBC Reconnaissance System led to interest in the German FUCHS NBC Reconnaissance System that utilized the TPz-1 Spurpanzer, a six-wheeled armored vehicle. During Operation Desert Shield in 1990, the Army issued the first XM93 series NBC Reconnaissance Systems (Fox)(NBCRS), type classified urgent, limited production (LPU). The XM93 Fox was a dedicated system of NBC detection, warning, and sampling equipment integrated into a high speed, high mobility armored carrier. The onboard detection devices included the MM-1 Mobile Mass Spectrometer, the M43A1 Chemical Agent Detector, the M256 Chemical Agent Detector Kit, the AN/VDR2 Radiation Detector, and ASG1 Radiation Detector. No biological agent detector was included, although the Fox provided biological agent protection for the crew. The Fox was capable of performing NBC reconnaissance on primary, secondary, or cross-country routes throughout the battlefield and had the capability to find and mark CB contamination. While conducting the reconnaissance, the four-man crew was protected by the inclusion of an on-board overpressure system. The initial production was 48 vehicles with an additional 65 vehicles rushed into the field during Operation Desert Shield. The use of the XM93 Fox in Operation Desert Storm quickly proved its value. In 1998, the limited production version was reclassified standard although all but 24 of the early Fox vehicles were converted to M93A1 versions.

***M93A1 NBC Reconnaissance System (FOX)***

The M93A1 version was standardized in 1996. The M93A1 Fox was an improvement over the earlier limited production version. The addition of an M21 Remote Sensing Chemical Agent Alarm gave it the capability to detect chemical contamination at a distance. A later addition will be the CB Mass Spectrometer that will provide both chemical and biological agent detection. Once chemical agents were detected, the Fox could automatically integrate contamination information from sensors with input from on-board navigation and meteorological systems and rapidly transmit the alert to the Maneuver Control System. The M93A1 also reduced the crew size from four to three soldiers. The first deployment of the upgraded Fox vehicles with the M21 Alarm was to Bosnia in 1995.[77]

# THE FUTURE

## *Chemical Agent Detectors*



***Joint Chemical Agent Detector (JCAD)***

The JCAD will be a combined portable monitoring and small point chemical agent detector for aircraft, shipboard, and individual soldier applications. This hand-held, pocket-sized detector is required to automatically detect, identify, and quantify chemical agents inside the aircraft or ship, providing protection for the individual soldier, sailor, airman, or marine. For the duration of the mission, the device must be sufficiently sensitive to warn aircrews before accumulation of a dose that will cause miosis or more severe effects. It must be resistant to the severe interferent environment on a naval vessel and be small and rugged for individual use.

***Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD)***

The JSLSCAD will be a state-of-the-art detection system designed to provide U.S. Forces with enhanced capability in detecting chemical warfare agents. It is a lightweight, passive and fully automatic detection system that scans the surrounding atmosphere for chemical warfare agent vapors. It furnishes on-the-move, 360-degree coverage from a variety of tactical and reconnaissance platforms at distances up to 5 kilometers. It is a second-generation system that significantly improves on the capabilities of the currently-fielded M21 Remote Sensing Chemical Agent Alarm. The JSLSCAD will provide war fighters with enhanced early warning to avoid chemically-contaminated battle spaces. When avoidance is not possible, the JSLSCAD will give personnel extra time to don Mission Oriented Protective Posture gear.[78]

## *Biological Agent Detectors*

***Short Range Biological Standoff Detection System (SR-BSDS)***

The concept of the SR-BSDS is to provide a first time biological standoff detection capability to provide early warning, activate existing warning systems, and alert other biological detectors. The system will employ ultraviolet laser and laser-induced fluorescence to detect biological aerosol clouds at a standoff distance up to five kilometers. The concept called for both fixed-site applications or mobile (vehicle and aircraft) applications. The SR-BSDS is currently undergoing testing.[79]

### *NBC Reconnaissance Systems*

***Joint Service Lightweight NBC Reconnaissance System (JSLNBCRS)***

The JSLNBCRS will provide point and standoff intelligence for real-time field assessment of NBC hazards. The system is a vehicle-mounted suite of equipment and software designed to detect, collect, analyze, mark, and disseminate NBC data. Two variants, the High Mobility Multipurpose Wheeled Vehicle and the Light Armored Vehicle, will house the same equipment and offer on-the- move, standoff capability, while providing an air-transportable system. Timely provision of automated, digital information meshed with meteorological and positioning information will provide commanders more options in merging NBC information with tactical, operational, and strategic plans.

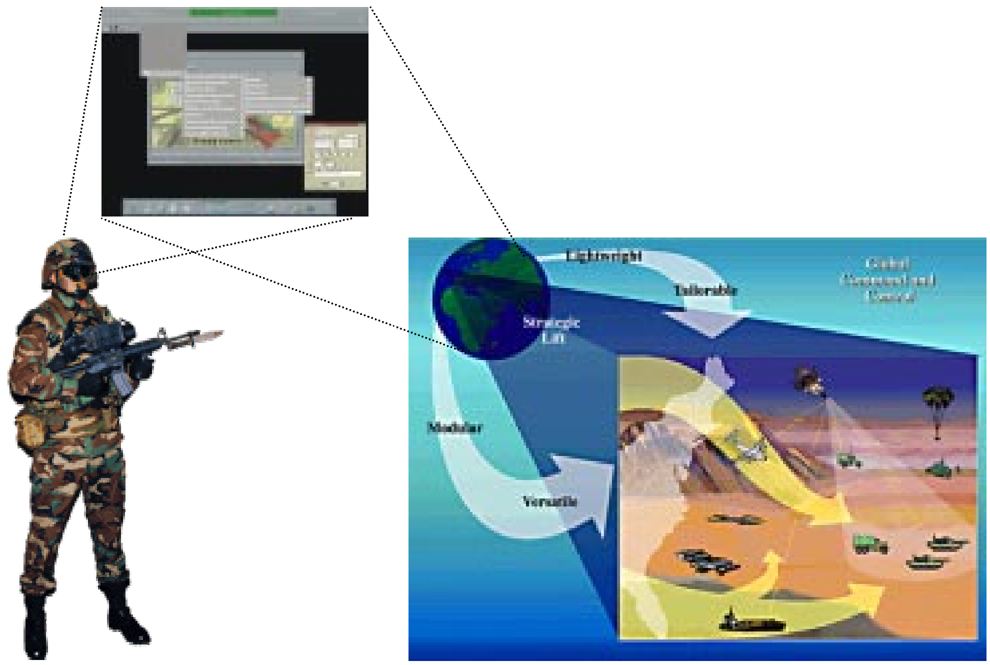
*Future NBC Recon*

The future reconnaissance system will provide overmatching capability as an integrated NBC reconnaissance, surveillance, detection, and identification system that can be employed anywhere on the battlefield. This system will increase the combat power of the deployed force and minimize force effectiveness degradation under NBC conditions. The core of the system will be its expandable, scaleable common technical architecture supporting C4ISR interoperability and an NBC sensor suite designed to accept enhancements such as remote sensing. Capabilities include on-the-move standoff chemical vapor detection, chemical and biological integrated detection, on-the-move micro-meteorology, and common technical architecture. The future NBC reconnaissance system will be designed for horizontal technology integration and remote sensor ready upgrades and advanced prognostics/diagnostics.

### *Fully Integrated NBC Protection*

***The Soldier of the Future***

The soldier of the future will have fully integrated NBC protection, sensors and information. Very lightweight, embedded sensors on the soldier will provide common, high fidelity NBC situational awareness. The objective is to make the sensors transparent to the warfighter, but the resulting information apparent.[80]



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